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Cyanide in Salmon and Brown Trout

By A. V. HOLDEN, B.A., and K. MARSDEN
Freshwater Fisheries Laboratory, Pitlochry

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Cyanide in Salmon and Brown Trout

INTRODUCTION

Cyanide has for long been recognised as a substance particularly toxic to fish, and mortalities among fresh water fish due to industrial effluents containing cyanide are fairly common. Electro-plating and metal-finishing processes in particular employ large quantities of sodium cyanide, some of which may accidentally pass into drains and thus to water courses. Sodium cyanide mixed with other chemicals, is also used in Great Britain as a vermin destroyer, particularly against rabbits, for which purpose it is sold as a scheduled poison under the trade-name 'Cymag'.

In this latter form the chemical has frequently been used as an illegal means of obtaining salmon (*Salmo salar*) from rivers, being rapid in action and leaving no visible evidence of damage to the fish. Poisoning of fish by this or other means is an offence under the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951; but there is evidence that poaching by this means has become more common in Scotland in recent years.

A method of analysis for traces of cyanide in fish tissue was developed for the diagnosis of poisoning, but the mere presence of cyanide proved to be insufficient evidence that poison had been used, as unpoisoned salmon were found to contain cyanide in very small quantities. An examination of the distribution of cyanide among a random sample of such fish from various sources was therefore made. The concentrations of cyanide which were found in some salmon believed to have been killed by the use of 'Cymag' were not markedly higher than those at the upper end of the range found among unpoisoned fish. A method of establishing whether dead salmon had been killed by cyanide poisoning was therefore required, and it was also clearly desirable that any loss of cyanide from the tissues prior to analysis should be reduced to the minimum. Several factors considered liable to cause such losses were investigated.

It was at first thought that the salmon removed from rivers by poachers were being killed by the application of sufficient 'Cymag' to produce a concentration of cyanide which was lethal in a very short time. The aqueous concentrations of cyanide used in the earlier investigations were consequently of the order of 50 p.p.m. Laboratory experiments were made, in the winter, to determine the concentrations of cyanide produced in salmon by various aqueous cyanide concentrations and periods of exposure. It was found that conditions resulting in death of the fish produced concentrations in the various tissues and organs which were much higher than those in fish submitted for analysis from poaching incidents. Nevertheless the factors causing losses of cyanide from tissues were studied in fish exposed to such conditions.

It was later suspected that many poachers, who are usually most active during the summer, were using quantities of 'Cymag' sufficient only to incapacitate the fish, enabling them to be removed from the water easily. The earlier laboratory experiments on salmon were carried out in winter at low temperatures, but a further series of experiments was made, in the summer of 1962, when the effects of much lower aqueous cyanide concentrations, sufficient only to incapacitate the fish in a short time, were studied. Such concentrations were found to be much lower than those required at the lower winter temperatures. Under these conditions, concentrations of cyanide in the fish tissues similar to those found in the fish submitted for examination from 'Cymag' incidents were obtained.

Poisoning of brown trout (*Salmo trutta*) is also an offence under the Salmon and Freshwater Fisheries (Protection) (Scotland) Act 1951, and samples of these fish are sometimes submitted for examination. This species was therefore studied in the same way, and being more easily obtainable than salmon was more suitable for some laboratory investigations. Certain factors were studied only with brown trout, and the close relation between the two species generally enabled the deductions made to be applied to salmon, although in certain instances the differences were rather large, possibly due to differences in size, rather than species.

Several practical difficulties were encountered during the investigations. For routine purposes gill filaments were found to be the most suitable analytical material, a weight of about 10 g. being preferable. This is easily obtained from salmon, but the brown trout used in the experimental work were too small to provide more than 1-2 g. from the gills, with a consequent slight reduction in the accuracy of the analyses.

The natural variation among fish frequently results in wide differences between individuals, but it was not normally found possible to use more than two fish to determine the effect of any one combination of factors during poisoning. All but a few of the salmon used were obtained during the winter. The supply of brown trout of a suitable size was also irregular, and they were of necessity obtained from more than one source.

As the experimental work was performed with these limitations, differences in the results due to size, sex, condition, maturity, source of fish or season of the year or, in the case of salmon, to their physiological condition due to their movement from sea to fresh water, could not be established. The possibility that one or more of these factors might influence the results must, however, be borne in mind when considering the variability among these results.

METHODS

The analytical method employed for the determination of cyanide in all organs and tissues was that described by Marsden (1959).

Dilutions of a standard solution of potassium cyanide were used in all experiments. As the duration of exposure to the poison was generally not more than thirty minutes and the volume of water used was large in relation to the fish, the aqueous concentrations have been assumed to be constant. It is recognised, however, that apart from the removal of a small quantity of cyanide by the fish there will have been a loss from the water surface following hydrolysis of the potassium cyanide. As the critical period of exposure to the solution was found to be about five minutes at low temperatures (and probably less at higher temperatures) these losses were considered to be of minor importance.

Salmon of approximately $1\frac{1}{2}$-3 kg. and brown trout weighing 100-500 g. were used. The stock of fish was kept in tanks similar to the test tank, and at the same temperature, and transferred to the test tank immediately after the appropriate addition of cyanide to the latter. No artificial aeration was given to the water after addition of the cyanide. The time elapsing before the first signs of reaction to the cyanide, or the time of death, were not normally recorded, as the object of the experiments was principally to study the influence of the external conditions on the resulting concentration of cyanide in the fish tissues.

RESULTS

(a) Cyanide Content of Unpoisoned Fish

Cyanide occurs naturally in the tissues of salmonids and although it is possible that the range and mean of cyanide concentrations in the tissues of a population of fish from one river may differ from those in another, this has not been examined, a random sample of fish from various rivers being used. The range and variance obtained may thus be greater than that to be expected from one particular river, but for the purpose of assessing the values of the cyanide contents of suspect fish only a comparison with the data from the widest distribution of healthy fish was practicable. For the same reason, possible differences in cyanide content due to sex or season have also been ignored.

The distribution of the cyanide concentrations in the gill filaments of 42 unpoisoned salmon was positively skewed (Marsden 1959). The mean, corrected for skewness, was 0·0137 p.p.m. and the 95% limits calculated from the logarithmic transformation were 0·0022 and 0·0483 p.p.m. Thus only one fish in forty in a natural population would be expected to contain cyanide in the gill filaments in excess of 0·048 p.p.m. (These limits are closer than those originally reported by Marsden (1959), as the result of a re-examination of the data, and improved accuracy of determination). Further, comparison of the mean of the logarithms of values from suspect fish with the value of 0·0137 p.p.m. given above enables an assessment to be made of the probability of the suspect fish being poisoned.

A similar series of analyses on 49 unpoisoned brown trout from various sources gave values closely resembling those for salmon, with a logarithmic mean value (corrected for skewness) of 0·0135 p.p.m. and 95% confidence limits of −0·0075 and +0·0740 p.p.m. The wider limits obtained are mainly due to the lower accuracy inherent in the use of the much smaller quantities of gill tissue available from trout.

Analyses of the brain, gills and liver of four unpoisoned trout stored at 10°C for six hours after death suggested that higher cyanide concentrations may sometimes be found in the brain than in the other two organs (Table 1). For all routine assay purposes, however, gill filaments were used, in view of the greater consistency in the results.

TABLE 1

Tissue	Cyanide Concentration (p.p.m.) in fish no.			
	1	2	3	4
Brain	0·090	0·015	0·037	0·130
Gill	0·011	0·014	0·014	0·010
Liver	0·006	0·013	0·006	0·027

The possibility that cyanide could be produced as a decomposition product of tissue during storage was next considered. A number of unpoisoned salmon from the same population were killed by a blow on the head and the gill filaments analysed for cyanide content after storage at a temperature of 8°C for periods up to 77·5 hours (Table 2). Although the shortest time of 1·5 hours gave the lowest cyanide

TABLE 2

Period of Storage (hrs)	Cyanide in Gills (p.p.m.)
1·5	0·003
4·5	0·012
6·5	0·010
29·5	0·010
77·5	0·008

concentration, there is no evidence of a significant increase in cyanide with storage time. The variance among the five fish was not significantly different from that of a number of fish stored for the same period.

(b) Factors Affecting Cyanide Content of Fish During Poisoning

The variation expected among individuals from one population was first assessed. Five male salmon were exposed to 50 p.p.m. cyanide solution at 4·5°C for 25 minutes, and the gill filaments analysed. The coefficient of variation found was 9·0%, the variation due to the analytical errors alone being only 1·2%. For brown trout the coefficient of variation was 20% at 16°C. The higher value for the coefficient in the case of trout was largely due to the lower accuracy of the determination inherent in the use of smaller amounts of tissue available, but may also have been partly attributable to the higher temperature.

(i) *External aqueous concentration*

Five pairs of male salmon ($\frac{3}{4}$-$2\frac{3}{4}$ kg.) were immersed in different concentrations of cyanide at 5·5°C for 30 minutes and stored at 8°C for 6 hours before analysis (Table 3).

TABLE 3

Aqueous Concentration (p.p.m.)	Concentration in Gills (p.p.m.)
5	0·94, 1·11
10	1·83, 2·30
25	—, 2·03
50	2·62, 2·71
125	6·32, 6·90

The concentration of cyanide in the gills is clearly dependent on the aqueous concentration.

Somewhat similar, but less regular, results were obtained with brown trout (150-500 g.) as shown in Table 4. Immersion time was 30 minutes at 4·5-6·2°C, and the fish were stored at 10°C for 6 hours before analysis.

TABLE 4

Aqueous Concentration (p.p.m.)	Concentration in Gills (p.p.m.)
5	0·53, 0·64
10	0·64, 1·18
25	2·39, 2·42
50	0·90, 1·87
75	2·72, 2·99
100	2·43, 4·15

(ii) *Time of immersion*

Five pairs of salmon (1·7-2·7 kg.) were immersed in an aqueous solution of 50 p.p.m. cyanide at 5·0°C for varying periods, and stored at 8°C for 6 hours before analysis. The concentrations of cyanide found in the gills were found to increase with immersion time as shown in Table 5.

TABLE 5

Period of Immersion (min.)	Concentration in Gills (p.p.m.)
10	0·95, 1·58
15	1·14, 1·57
20	1·81, 1·95
25	1·79, 2·14
30	2·31, 2·62

Similar results were obtained with brown trout, not only in the gills but also in the brain and liver. The fish were immersed in 50 p.p.m. cyanide solution at 3·0°C and stored at 15°C for 6 hours. As shown in Table 6, the concentrations in the liver were higher than those in the gills.

TABLE 6

Period of Immersion (min.)	Concentration of Cyanide (p.p.m.)		
	Gills	Brain	Liver
10	0·62, 0·89	0·68, 0·71	1·01, 1·65
15	0·82, 0·82	0·60, 0·69	1·33, 1·42
20	1·55, 1·56	1·08, 2·30	2·24, 2·38
25	1·78, 1·79	2·24, 2·38	2·04, 3·00

In contrast to these results obtained at a low water temperature, brown trout immersed at 20°C in 50 p.p.m. cyanide solution for varying times, and stored at 20°C for 6 hours before analysis, showed little variation in cyanide content in the gills (Table 7). Death occurred within 30 minutes, and there was no evidence of any significant absorption of cyanide after death.

TABLE 7

Period of Immersion (min.)	Concentration in Gills (p.p.m.)
5	0·58, 0·59
10	0·49, 0·71
20	0·59, 0·69
30	0·75, 0·87
60	0·79, 0·95

(iii) *Temperature of immersion*

The concentrations given in Table 7 for the longer periods of immersion are much lower than those given in Table 6, suggesting that either immersion or storage, or both, at the higher temperature of 20°C may have been responsible. To clarify this point, four pairs of brown trout were immersed in 50 p.p.m. cyanide solution at two temperatures, 7·0°C and 18·5°C, for periods of 10 and 30 minutes, and the gills, brain and liver analysed after storage for 6 hours at 10°C (Table 8). All the fish were alive on removal from the cyanide solution except those exposed for 30 minutes at 18·5°C.

TABLE 8

Temperature (°C)	Period of Immersion (min.)	Concentration of Cyanide (p.p.m.)		
		Gills	Brain	Liver
7·0	10	0·87, 1·53	0·62, 0·79	1·12, 1·16
	30	2·19, 2·24	1·41, 2·80	3·58, 3·91
18·5	10	0·76, 1·12	0·72, 1·15	1·05, 1·66
	30	1·44, 2·62	1·45, 1·96	3·51, 3·59

The effect of immersion time on the cyanide content is more marked than that of temperature which, over the range examined (7·0-18·5°C), appears to be of little significance. The relatively high concentrations found in the liver after 30 minutes at both low and high temperatures suggest that there is some accumulation of cyanide in this organ.

(iv) *Conditions producing low internal concentrations*

The experiments so far described had indicated that a combination of low external concentration and short immersion time might produce a low cyanide concentration in the gills, of a similar order to those frequently found in fish suspected to have been poisoned by 'Cymag'. However, it was also quite evident that such a combination, at low temperatures, would be insufficient to cause any reaction by the fish within the short periods of immersion considered. On the other hand, the effect might be more rapid at higher temperatures. It became possible, at a later stage of the investigation, to examine the combined effects of low aqueous concentrations and short immersion times at summer temperatures, and to study the reactions of the fish.

Pairs of salmon (1·9-3·1 kg.) were immersed in aqueous cyanide concentrations over the range 0·2-2·0 p.p.m. at 12·5-13·7°C, and the fish removed when obviously distressed. After killing by a blow on the head, and storing for 3-7 hours at 12-15°C, the fish were deep-frozen for a period before dissection and analysis. The loss of cyanide during the period of storage at 12-15°C is likely to have been small (see Table 10). The results are given in Table 9.

TABLE 9

Aqueous Concentration of Cyanide (p.p.m.)	Time of Immersion (min.)	Concentration of Cyanide (p.p.m.)		
		Gills	Brain	Liver
0·2	7	0·036, 0·037	0·140, 0·190	0·046, 0·048
0·5	5	0·050, 0·051	0·150, 0·207	0·038, 0·052
1·0	5	0·080, 0·110	0·115, 0·117	0·062, 0·106
2·0	3	0·125, 0·129	0·111, 0·116	0·092, 0·104

The most striking feature of this experiment was the very rapid reaction of the fish to the very low concentrations of cyanide. It was evident that poachers using low cyanide concentrations during the summer, when temperatures similar to those of the above experiment occur, would be able to remove salmon from a river very shortly after adding the cyanide. The concentrations of cyanide found in the gills of the salmon exposed to 0·2-1·0 p.p.m. aqueous cyanide concentrations were of the same order as those found in fish submitted for examination for possible cyanide poisoning, and the lowest levels were

within the range already established for healthy fish. The experimental fish, it must be emphasised, were removed as soon as they lost equilibrium, and did not die while immersed. Longer immersion produced higher concentrations in the tissues, as described below, but fish sent in for examination have often been found dead in the river, and can be assumed to have died after exposure for a longer period than that required to produce loss of equilibrium.

Sea trout (0·7-1·5 kg.) immersed in cyanide solution for 30 minutes at 12·6-13·0°C, a period longer than that producing death, and much longer than that causing distress, yielded much higher concentrations of cyanide in the tissues than those found in fish removed when distressed (Table 10). One pair of fish was stored at 15°C for 37 hours before dissection, while all other fish were deep-frozen for all but the first three hours after removal from the cyanide solution.

TABLE 10

Aqueous Concentration of Cyanide (p.p.m.)	Time of Immersion (min.)	Concentration of Cyanide (p.p.m.)		
		Gills	Brain	Liver
1·0	30	0·176, 0·187	0·094, 0·107	0·050, 0·055
1·0[a]	30	0·150, 0·153	0·028, 0·097	0·043, 0·053
5·0	30	0·519, 0·585	0·108, 0·164	0·210, 0·266
5·0[b]	3·5	0·166, 0·170	0·085, 0·174	0·161, 0·213

[a] Fish stored at 15°C for 37 hours before analysis.
[b] Fish removed when distressed.

The effect of storage at 15°C as compared with deep-freezing appears to be small in this experiment, but prolonged immersion in 5 p.p.m. cyanide solution, at least until death, resulted in appreciably higher cyanide concentrations in the gills, although the differences are less significant in the brain and liver. After 3·5 minutes, the concentrations in the liver were similar to those in the gills, but after longer immersion there is little further change in the liver, in contrast to a considerable increase in the gills. This suggests that transfer to the liver ceases at an early stage, while the accumulation in the gills continues at least until death.

The cyanide concentrations in the brain were also very high after only a short immersion period, but the increase with increasing aqueous concentration was insignificant. The level reached in the brain is possibly associated with the symptoms of distress. As in earlier experiments with salmon, the concentrations found in the liver were similar to or less than those in the gills, in contrast to the results for brown trout, where the liver concentrations were usually the higher.

(c) Factors Affecting Cyanide Content of Fish After Death

There is normally an interval between the death of fish from cyanide pollution and the preparation of specimens for analysis. This period may be as long as two days but in many instances is less than twenty-four hours. The ambient temperature may be as high as 20°C, particularly during the summer. Both these factors were considered to be possible reasons for loss of cyanide from dead fish, and were investigated.

(i) *Conditions of storage*

Six salmon exposed to 50 p.p.m. cyanide solution at 4·0°C were analysed after various periods of storage at 8·0°C (Table 11).

TABLE 11

Period of Storage (hrs)	Concentration in Gills (p.p.m.)
1·5	2·56
2·5	2·32
4·6	2·53
8·7	1·80
24·6	1·10
73·8	0·56

The loss of cyanide is slow for the first few hours, suggesting that little would be lost in the six-hour period of storage used in the experimental work. After 24 hours a 60% loss had occurred, and 80% after three days.

The effect of a high storage temperature on the cyanide content was studied with brown trout. Six pairs of trout were exposed to 50 p.p.m. cyanide solution at 16°C for 30 minutes, and subsequently stored at 20°C before analysis (Table 12).

TABLE 12

Period of Storage (hrs)	Concentration in Gills (p.p.m.)
1·5	1·54, 2·07
2·5	1·20, 2·22
4·5	1·03, 1·04
7·0	0·66, 0·83
24·0	0·74, 0·80
72·0	0·49, 0·69

As compared with the results for salmon stored at 8°C (Table 11), the values in Table 12 show that the loss of cyanide is more rapid at 20°C, at least 60% being lost in 7 hours, although the rate of loss is subsequently much slower.

(ii) *Removal of fish from water before death*

It was shown earlier that fish exposed to cyanide concentrations at high temperatures for periods insufficient to cause death contained much smaller quantities of cyanide than those found in fish allowed to die in the cyanide solution (Table 10). Fish poisoned by cyanide in a river, in their reaction to the poison, may well jump from the water to the bank and subsequently die there. Such fish would not appear to lose any significant quantity of cyanide while on the bank, although the amount contained in the gills is dependent on the time of immersion in the water. A comparison of the cyanide contents of salmon killed immediately after removal from 50 p.p.m. cyanide solution at 5·0°C and fish allowed to die in air after removal, is shown in Table 13.

TABLE 13

Time of Immersion (min.)	Concentration in Gills (p.p.m.)	
	Fish killed	Fish allowed to die
10	0·95, 1·57	0·98, 1·09
15	1·14, 1·56	1·56, 1·84
20	1·79, 1·95	1·34, 1·78
25	1·79, 2·12	2·48, 2·56

(iii) *Prolonged immersion in water after death*

Fish are sometimes found dead many hours after poisoning is known to have occurred. Tests with dead trout immersed in running water for periods up to four hours after poisoning indicated that no significant loss of cyanide occurred from the gills, brain or liver. Immersion for a much longer period would result in losses at least as large as those found after a similar period of storage out of water.

DISCUSSION

The foregoing account of the results of experiments on salmon and trout under widely varying conditions of temperature, aqueous cyanide concentration and time of exposure has shown that the concentration of cyanide found in the gill tissues after such exposure may vary from about 0·03 p.p.m. up to at least 7 p.p.m. The concentrations found in unpoisoned fish average about 0·014 p.p.m. but values up to 0·05 p.p.m. can occur occasionally. Thus there is the possibility that individual fish subjected

to cyanide concentrations under certain conditions may contain cyanide levels in the gills which are indistinguishable from natural levels. A sample of several fish, however, should enable a definite diagnosis of cyanide poisoning to be made on the basis that high values will occur infrequently in a natural population.

The low values in fish subjected to cyanide poisoning were obtained only at high (summer) water

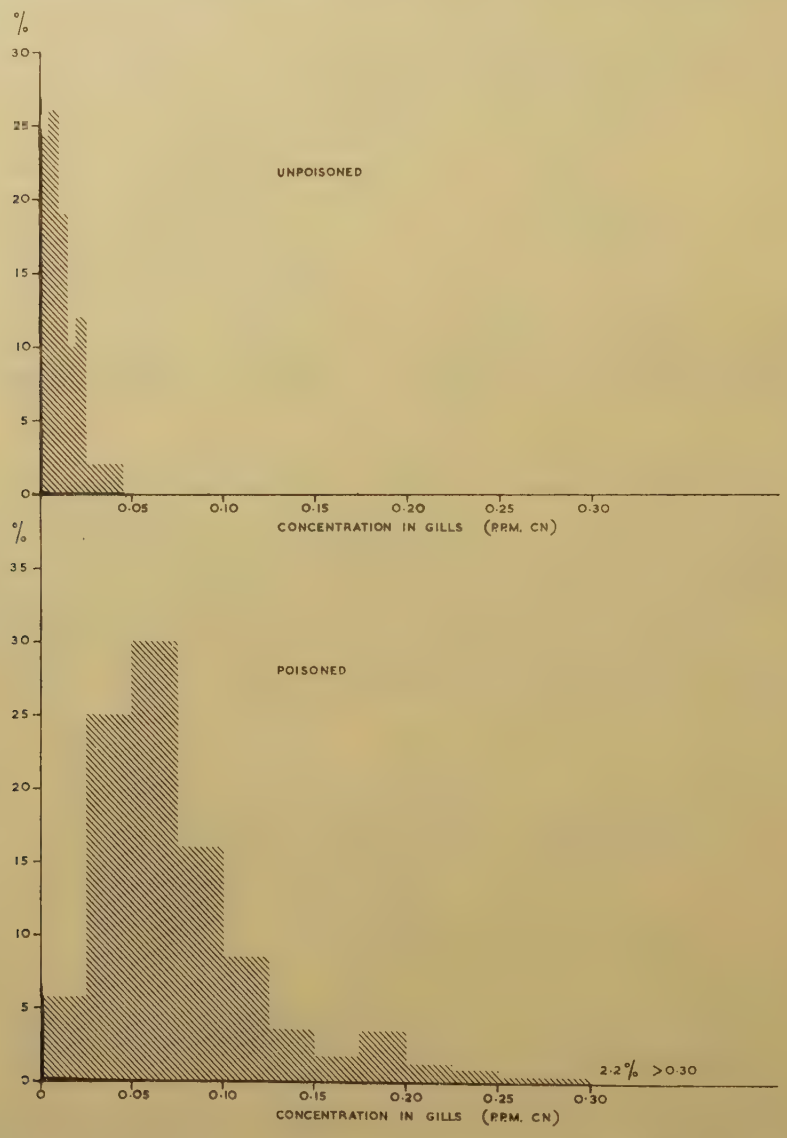

Fig. 1. Distribution of cyanide concentrations among unpoisoned and poisoned salmon.

temperatures of 12-14°C, at which level salmon are very sensitive to low cyanide concentrations (0·2-0·5 p.p.m.) and become distressed in a few minutes. The fish can at this stage be removed from the water without difficulty. If somewhat higher aqueous concentrations (1·0-5·0 p.p.m.) are used, the reaction time is shorter (3-5 minutes) but the concentration found in the gills is then appreciably higher (0·08-0·17 p.p.m.) and outside the natural range. If the poisoning occurs at lower temperatures, as in the early spring, the time taken to react is longer, and higher aqueous concentrations are necessary. Such conditions may result in higher concentrations in the gills. Furthermore, fish exposed to unduly high cyanide concentrations, such as may occur in instances of industrial pollution, whether at low or

high temperatures, will take up sufficient cyanide to yield easily measurable concentrations in the gills, which may be of the order of 0·1 p.p.m. or higher, even though the period of discharge is brief.

After death, cyanide is lost from the tissues during storage, particularly after the first few hours, the rate being more rapid at higher temperatures. Immersion in clean running water for a few hours after death causes no significant loss.

Following a poisoning incident, it is often observed that small fish are absent. Several possible reasons could be suggested for this. The smaller fish may escape the main stream of poisoned water because they are in the shallow water at the edge of the river, where concentrations of cyanide will be lower. Secondly, small fish which are affected are more easily swept downstream for some distance, where they may recover in less toxic conditions. It is also possible that small fish are more resistant to cyanide than large fish. Herbert and Merkens (1952) found this to be true over the size range of rainbow trout used in their experiments (5·5-17·25 cm.). The mean survival period for the smallest fish was 2·5 times that for the largest. In the present experiments, trout of 100-150 g. appeared to be more resistant to cyanide than salmon of 2-3 kg. under similar conditions. It may also be true that salmon which have recently entered a river from the sea are more sensitive to toxic conditions than fish not recently subjected to the physiological stresses of the change from sea to fresh water.

Over 250 salmon have been analysed as the result of mortalities known or believed to have been caused by 'Cymag' poisoning. Of these fish 94% contained cyanide concentrations in the gills exceeding 0·025 p.p.m. Of the unpoisoned salmon examined, only 8% had cyanide contents exceeding this value. As described earlier, the logarithmic distribution of the concentrations found in a population of unpoisoned fish results in the possibility that only 2·5% of the population could contain more than 0·048 p.p.m. of cyanide. Fig. 1 illustrates the frequency distribution of the two groups of analyses.

In a few instances, it has been found that some fish, from a sample submitted following a poisoning incident, have low cyanide contents, while others give high values. The presence of the high values in such a sample is normally sufficient evidence of poisoning, however. A sample of not less than five fish from a poisoning incident will normally include at least two values of cyanide concentration from gill tissue which are well beyond the normal limits for unpoisoned fish. The other values will also be rather high relative to the mean value for unpoisoned fish, and there is, therefore, usually no difficulty in distinguishing such values from those expected in a sample of unpoisoned fish, in view of the bias towards the lower concentrations in the latter.

Apart from the factors studied in this investigation, it is probable that polluting conditions will sometimes increase the sensitivity of fish to cyanide. For instance, the presence of low oxygen concentrations or other toxic chemicals in addition to cyanide, may cause death, although the cyanide concentration alone might be sub-lethal. Under such conditions the level of cyanide in the gills might well be indistinguishable from that in unpoisoned fish. The present investigation was not extended to cover such eventualities, most Scottish salmon rivers being relatively free from pollution and well oxygenated.

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SUMMARY

1. A study has been made of cyanide concentrations in the tissues of salmon and brown trout exposed to lethal aqueous cyanide solutions, for comparison with those in unpoisoned fish, as an aid to the diagnosis of cyanide poisoning.
2. The distribution of natural cyanide concentrations in the gills of salmon and brown trout has been investigated. For both species, this distribution exhibits a slight positive skewness with a mean of approximately 0·014 p.p.m. cyanide.

3. Salmon and trout killed by exposure to lethal aqueous cyanide concentrations contain cyanide concentrations in the gills which are much greater than those in unpoisoned fish.
4. The cyanide concentration in the gills increases with immersion time until death.
5. At a constant immersion time the cyanide concentration in the gills is proportional to the external aqueous cyanide concentration.
6. Cyanide is lost from the tissues during storage after death, but the loss is slow for the first few hours at low temperatures. At higher temperatures the loss is more rapid.
7. The effect of temperature on the cyanide concentration in the gills is less marked during poisoning than during storage.
8. Salmon exposed to low aqueous cyanide concentrations at high temperatures for a period sufficient only to cause distress contain much lower cyanide concentrations in the gills than those allowed to die in the toxic solution. At the lowest aqueous concentration tested (0·2 p.p.m. cyanide) the concentration of cyanide found in the gills was similar to that which could occur naturally.
9. High cyanide concentrations were also found in the brain and liver of poisoned fish. Trout generally had higher concentrations in the liver than in the gills, but in salmon the order was reversed.
10. The absence of small fish from those killed in a typical poisoning incident is discussed and it would appear that small fish have a greater resistance to cyanide poisoning than large fish, especially fresh-run salmon.

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